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GLOBAL VIEW OF THE ORIGIN OF TROPICAL DISTURBANCES AND STORMS

WILLIAM M. GRAY

Department of Atmospheric Science, Colorado State University, Fort Collins, Colo.

ABSTRACT

A global observational study of atmospheric conditions associated with tropical disturbance and storm development is presented. This study primarily uses upper air observations which have become available over the tropical oceans in the last decade. Climatological values of vertical stability, low level wind, tropospheric vertical wind shear and other parameters relative to the location and seasons of tropical disturbance and storm development are discussed. Individual storm data are also presented in summary form for over 300 development cases (with over 1,500 individual observation times) for four tropical storm genesis areas.

Results show that most tropical disturbances and storms form in regions equatorward of 20° lat. on the poleward side of doldrum Equatorial Troughs where the tropospheric vertical shear of horizontal wind (i.e., baroclinicity) is a minimum or zero. Storm development occurring on the poleward side of 20° lat. in the Northwest Atlantic and Northwest Pacific takes place under significantly different environmental conditions, which are described. These latter developments make up but a small percentage of the global total.

Observations are also presented which indicate that over the tropical oceans where disturbances and storms form, there is a distinct Ekman or frictional veering of the wind in the subcloud layer (surface to 600 m.) of approximately 10°. This produces or enhances synoptic-scale low level convergence and cumulus convection in regions of large positive relative vorticity which exist in the cyclonic wind shear areas surrounding doldrum Equatorial Troughs.

Tropical disturbance and later storm development is viewed as primarily a result of large-scale Ekman or frictionally forced surface convergence (with resulting cumulus production and tropospheric heating), and a consequent inhibition of tropospheric ventilation by initially existing small vertical wind shear, and later inhibition of ventilation by cumulus up- and downdrafts acting to prevent increase of vertical shear as baroclinicity increases. The above processes produce the necessary condensation heating and allow for its concentration and containment in selective areas. Development is thus explained from a simple warming, hydrostatic adjustment point of view with the energy source analogous to Charney and Eliassen's proposed "conditional instability of the second kind."

CONTENTS

1. INTRODUCTION

General agreement on the environmental conditions and the physical mechanisms which bring about tropical disturbance and tropical storm development is lacking. Meteorologists in various parts of the world emphasize and discuss different onset and development criteria, but the basic physical processes which accompany the development of these warm-core cyclones must be very similar. This lack of general agreement, while partly due to semantic differences, is primarily explained by deficient observational evidence from which early empirically based conclusions could have been established.

Riehl [24, 25, 26] has viewed the formation process, in general, as a progressive intensification of a westerly moving disturbance or wave embedded in the trade winds which moves under a favorable upper tropospheric divergent environment. He was the first to point out the association of typical upper and lower tropospheric flow patterns prior to disturbance intensification. In a broad sense, Yanai [35] and Fett [13, 14] have agreed with Riehl with regard to wave or disturbance progressive intensification within a trade wind environment. Yanai looks to deep, broad-scale vorticity convergence as an important initial requirement. From a similar point of view, Dunn [11] and others earlier observed that intensification in the North Atlantic occurs from westerly moving isallobaric waves within the trade winds.

Sadler [29, 30, 31], Tanabe [34], Ramage [23], and Gabites [15], all of whom have primarily studied Pacific storms, have advanced other opinions on development. Sadler observes storm intensifications as occurring from an initially established surface equatorial trough vortex or from the downward tropospheric intensification of a preexisting upper tropospheric trough. Ramage looks to an energy dispersion mechanism from a midoceanic upper troposphere trough as a favorable initiator of upper divergence over an incipient disturbance. Tanabe observes a strong association of development with the position of the Equatorial Trough. When discussing tropical storm development, Gabites has stated, "In the southwest Pacific it is evident that easterly waves play very little part." Is it likely that development conditions would be different in the various parts of the globe? The author feels there must be a basic similarity of development.

Upper air information over the tropical oceans was very sparse until the middle 1950's. The addition of new upper air stations in the Tropics and the development of the weather satellites has substantially added to our observational information. With these new data it is now possible to obtain a more unified global view of tropical disturbance and storm development. The purpose of this paper is to present observational information on the environmental conditions surrounding tropical disturbances which later develop into tropical storms in order to obtain a better understanding of the relevant physical processes concerning development. In the author's opinion, there has been too much qualitative and incomplete reasoning concerning the physical processes of development. General conclusions have been drawn from atypical case studies. Theories of development have been advanced without supporting data or plausible physical substantiation. Numerical model experiments have been made where initial assumptions are not realistic. In order to organize more realistically the information on this subject, the author has chosen to take the empirical approach and go directly to the observations.

2. GLOBAL CLIMATOLOGY OF STORM DEVELOPMENT

LOCATION AND FREQUENCY OF INITIALLY OBSERVED DISTURBANCES AND STORMS

The small dots of figure 1 show where initial disturbances from which tropical storms later develop were first detected. As the number of years of available records for the different areas are not equal, these dots should not be considered to be representative of relative storm frequency.[1] Recent satellite information indicates that the majority of the locations of initial detection in the NW Atlantic [2] (where data have been especially scarce) should be relocated in the Cape Verde Island area or over west-central Africa, as discussed by Aspliden et al. [5], and Arnold [4]. In other development areas the location of many initial disturbances might be more realistically located slightly to the east of the positions shown.

In this paper, tropical storms will be defined as warm-core cyclonically rotating wind systems in which the maximum sustained winds are 35 kt. (i.e., 40 m.p.h.) or greater. Hurricanes, typhoons, and cyclones (Southern Hemisphere) are also included in this definition.[3]

[1] Data sources are listed in Appendix.

[2] The following contractions are used throughout this paper—NW Atlantic for Western North Atlantic, NE Pacific for Eastern North Pacific, NW Pacific for Western North Pacific, etc.

[3] As defined by the WMO (*Glossary of Meteorology*, 1959), a tropical storm has sustained winds of 40 m.p.h. or greater; a hurricane, typhoon, or cyclone (of the Southern Hemisphere) has sustained winds of at least 75 m.p.h. In this paper the term tropical storms as defined refers to both tropical storms and to hurricanes. The physical mechanisms which operate to produce storms of 40 to 75 m.p.h. and those which produce storms with winds greater than 75 m.p.h. are assumed to be similar. The U.S. Weather Bureau has slightly different definitions for tropical storms and hurricanes.

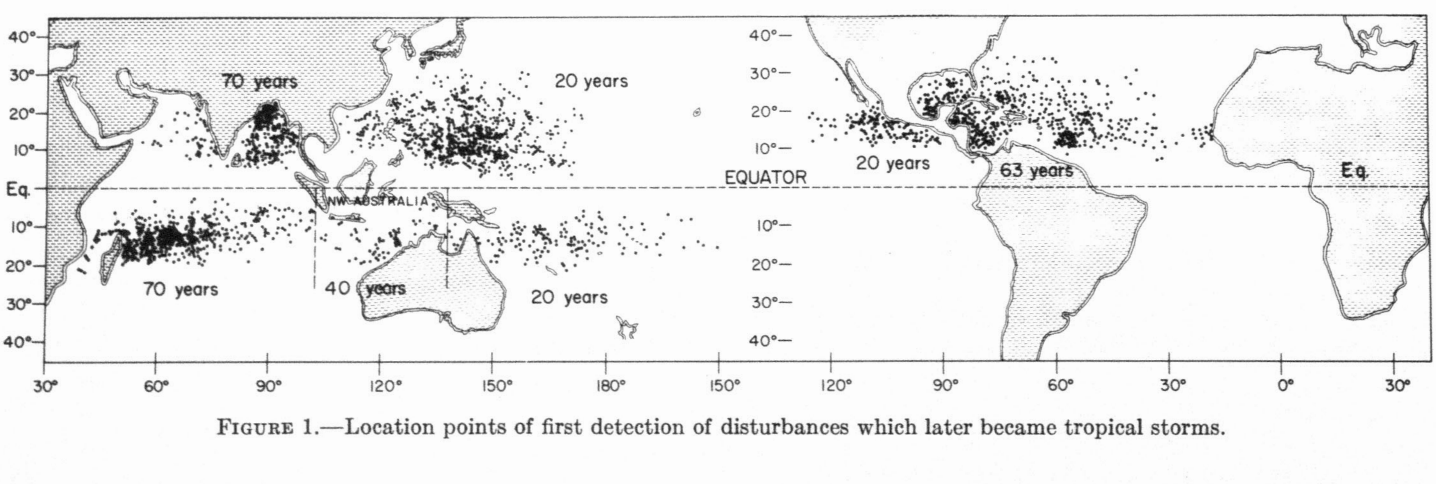

FIGURE 1.—Location points of first detection of disturbances which later became tropical storms.